Technical Report 172

RADIOLOGICAL DECONTAMINATION SWEEPER

18 October 1961

U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

RADIOLOGICAL DECONTAMINATION SWEEPER

Y-F011-05-203

Type C   Final Report

by

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OBJECT OF TASK

To develop or evaluate a motorized pavement sweeper capable of picking up and retaining fallout material until suitable disposal can be made.

ABSTRACT

Three types of pavement sweepers were investigated to determine their adaptability for high-rate radiological decontamination. A runway sweeper utilizing an air nozzle pickup was found to be not adaptable. Ordinary street sweepers can perform limited services as decontamination sweepers, but are not suitable for complete development as high-rate units.

A sweeper developed for Air Force decontamination needs, the ARDC 100DS, is adaptable to the task requirements.

INTRODUCTION

Radioactive fallout contamination of naval bases could immobilize them for considerable periods of time. Natural decay gradually reduces the radioactivity of the fallout, but in many cases it can be expected that the bases must be cleaned up as soon as possible to allow performance of a military mission. Much of the base area may be paved and removal of fallout from the paved surfaces is one of the most important aspects of base recovery.

A number of methods of pavement decontamination have been available. These include firehosing, hand sweeping, flushing with motorized pavement flushers, and the use of street or runway sweepers. Generally the wet methods, firehosing and flushing, are very effective, but they depend on ample quantities of water and good drainage. Because street and runway sweepers appeared to offer a good potential for rapid decontamination without dependence on water and drainage, this laboratory was given the assignment to investigate the feasibility of pavement-decontamination sweepers and to discover or develop a sweeper for rapid radiological decontamination.

DECONTAMINATION REQUIREMENTS

BuDocks' instructions for this task specified the following characteristics and capabilities for a high-rate radiological decontamination sweeper:

1. It is to operate on dry fallout (size not specified) with a specific gravity of 2.5, deposited in amounts up to 0.25 pounds per square foot.

2. It is to be capable of sweeping at a rate of 150,000 square feet per hour.

3. It is to be capable of pickup and retention of 95 percent of the fallout.

4. The exhaust air from any filter system on the sweeper should not contain any particles over 10 microns in diameter.

5. Operating personnel must be protected from radiation, but preferably not by means of remote-control operation.

6. The maximum travel speed should be 25 mph and the maximum sweeping speed should be 10 mph.

7. Right- and left-hand gutter brooms should be included in the sweeper equipment.

8. The sweeper should be highly maneuverable, with an outside turning radius of 10 feet.

9. The hopper capacity should be 3 to 5 cubic yards.

10. The hopper should dump quickly and completely.

11. The sweeper should be easily decontaminated.

A further analysis of requirements was made by the Laboratory and reported in NCEL Technical Note 376.[1] This analysis provided further information on requirements 3, 4, and 5 to permit an evaluation of commercially available sweepers and to determine what technical developments were required to provide a satisfactory decontamination sweeper. The analysis in TN-376 showed that 95 percent decontamination effectiveness as indicated in item 3 is a good general average of required pavement cleaning, but that an effectiveness up to 99 percent (RN = .01) might be needed for some situations. The analysis[1] of item 4, exhaust air standards, showed that a size limit of 10 microns was probably too rigid because of the limited number of small particles involved. It even appeared that there was a possibility that all particles under 25 microns were so few in number that they might be ignored without causing undue fallout redistribution in the decontamination sweeping process. Since that time some further information has become available, but a significant, clearly defined, lower size limit is not yet established. When established, a lower size limit will be significant in determining the dust separation requirements for vacuumized or air-stream sweepers. Data so far available indicates little significance in very small particles. Anderson[2] has presented an analysis of size distribution for a particular instance of fallout conditions, but does not show data for particles less than 80 microns. Chan[3] shows data from several fallout occurrences, with sizes ranging down to 10 microns but with very small fractions of the total radioactivity associated with particles less than 30 microns. On the basis of this presently available information, the 10-micron limit set by the Bureau is a safely conservative figure.

The subject of requirement 5, protection of operating personnel, is important for all types of decontamination. TN-376 indicates that the type of protection required depends on the allowable dose and the time at which fallout decontamination is started. Shielding requirements are very high if cleanup is started within 12 hours after the nuclear explosion, and remote controlling would be necessary in very strong fallout fields. Shielding thickness and weights become more reasonable at later times, and requirement 5 can be met by shielding and by operaror rotation in accordance with the principles set up in TP-PL-13.[4]

This analysis indicated that a practical sweeper based on the Bureau's specification was possible, and a further investigation of commercial and military sweepers was undertaken.

REVIEW OF COMMERCIAL AND MILITARY SWEEPERS

Just a few years ago, the only type of sweeper available was the familiar street sweeper with a horizontal rotary broom and gutter brooms. Recently the commercial market has broadened to include sweepers with vacuum dust control and runway sweepers using air streams or brooms or combinations of these. Two sweepers designed for the Air Force are also now available. One of these, the MC-1, was designed as a runway sweeper. The other, a prototype called the 100DS, was designed specifically as a decontamination sweeper for the Air Research and Development Command.

This laboratory's studies of decontamination sweepers have covered three types of sweepers: (1) the AF MC-1, (2) the ARDC 100DS, and (3) ordinary street sweepers. Work began with a feasibility study contract on the possibility of converting the Air Force MC-1 runway sweeper. This sweeper uses a high-velocity air stream and discharges large quantities of unfiltered air. The study[5] showed that a trailer-mounted dust-control attachment would be needed to convert the unit. The cost of conversion and the awkwardness of the trailer made this unit impractical for decontamination use. Table I compares features of this and other sweepers with the BuDocks requirements.

The second type considered, the ARDC 100DS decontamination sweeper, is a rotary-broom sweeper with a vacuum dust-control system, an airbroom (air jets designed to loosen dust from the pavement), and remote controls.

Because of the extensive development program undertaken by the Air Force Special Weapons Center in connection with this ARDC decontamination sweeper, NCEL has recently confined its efforts to observation of this sweeper's development and to consideration of a third possibility, conversion of ordinary street sweepers. The technical requirements and feasibility of converting readily available street sweepers for decontamination were analyzed by study of an available sweeper. These last two programs are discussed in the next two sections.

ARDC 100DS DECONTAMINATION SWEEPER

The ARDC 100DS meets or exceeds most of the BuDocks specifications for a decontamination sweeper. This sweeper was designed for remotely controlled clean-up of runways and ramps, and extensive data was obtained by NRDL for both remote and direct manual operation. Information on this sweeper is summarized in Reference 6. Figure 1 shows the remote-control unit and Figure 2 diagrams the sweeping system. Table I compares the findings in Reference 6 for the 100DS sweeper with BuDocks specifications. The 100DS also has certain features not specified by BuDocks. It is air-transportable in a C-124 and is adaptable for normal runway sweeping operation. In general, Table I shows that the Unit was designed for somewhat greater capability than required in the BuDocks specifications. Speed and decontamination effectiveness are somewhat greater and the sweeping rate potential is very good. A deficiency from specifications exists in the 100DS turning radius, and in the fact that no gutter brooms are provided. The cost of a 100DS without remote controls would be about $20,000. It provides no operator shielding, but is large enough to carry a considerable amount of lead.

STREET SWEEPER CONVERSION

Preliminary Considerations

Test results from NRDL studies on pavement decontamination[7,8] showed that ordinary street sweepers have considerable decontamination capability. Efficiencies of about 90 percent are shown, although two or three passes were sometimes necessary to achieve maximum effectiveness. Because street sweepers are available at most bases, they are potentially valuable decontamination tools. Several important questions exist concerning the economical conversion of typical sweepers. The early tests at Camp Stoneman showed that a typical sweeper caused considerable dust blowing. Use of the sweeper water-spray system resulted in some dust control but caused poor pickup results. According to information received from Mr. Donald Clark of NRDL, a vacuumized sweeper used in later tests gave better decontamination effectiveness without a dusting problem.

Another important consideration in the application of street sweepers to decontamination purposes is the problem of operator protection. Use of the sweeper on fresh fallout would require shielding, particularly of the hopper. As sweeping progresses, several yards of fallout would be lodged in the hopper, resulting in large quantities of radiation. Reference 1 shows that up to 1-1/2 inches of lead shielding would be needed to start operations at 12 hours in a fallout field.

Table 1. Specification Comparison for 100DS Sweeper

Criterion	BuDocks Spec	100DS Sweeper	MC-1	Converted Street Sweeper (Estimated)
Sweeping rate	150,000 ft^2/hr	185,000 ft^2/hr (based on 10-mph sweeping speed and 50% haul and dump time)	210,000 ft^2/hr (based on 10 mph and 50% haul and dump time)	22,500 ft^2/hr
Percent pickup	95%	99.8% (manual operation)	95%	90% - 98% (varies with brand)
Exhaust air dust	Particles less than 5 microns	Not tested - No measurable activity in tests on identical system	2500 cfm heavily contaminated	Blowing dust with some brands
Operator protection	Degree unspecified	Remote controls	None - Light shielding possible	Light shielding
Travel speed	0 - 25 mph	0 - 35 mph	0 - 25 mph	0 - 10 mph
Sweeping speed	0 - 10 mph	0 - 35 mph (efficiency diminishes above 10 mph)	0 - 25 mph	0 - 3 mph
Gutter broom	Right and left hand	None	None	Right and left hand
Maneuverability	10-ft turning radius	20-ft turning radius	30-ft turning radius	10-ft turning radius
Hopper	3 - 5 yd	4 yd	4 yd	3 yd
Dump time	Quick and easy	30 seconds	30 - 60 seconds	30 - 60 seconds
Unit decontaminability	Quick and easy	Not tested - Hopper easily washed; filter bags removable	Not tested	Not tested

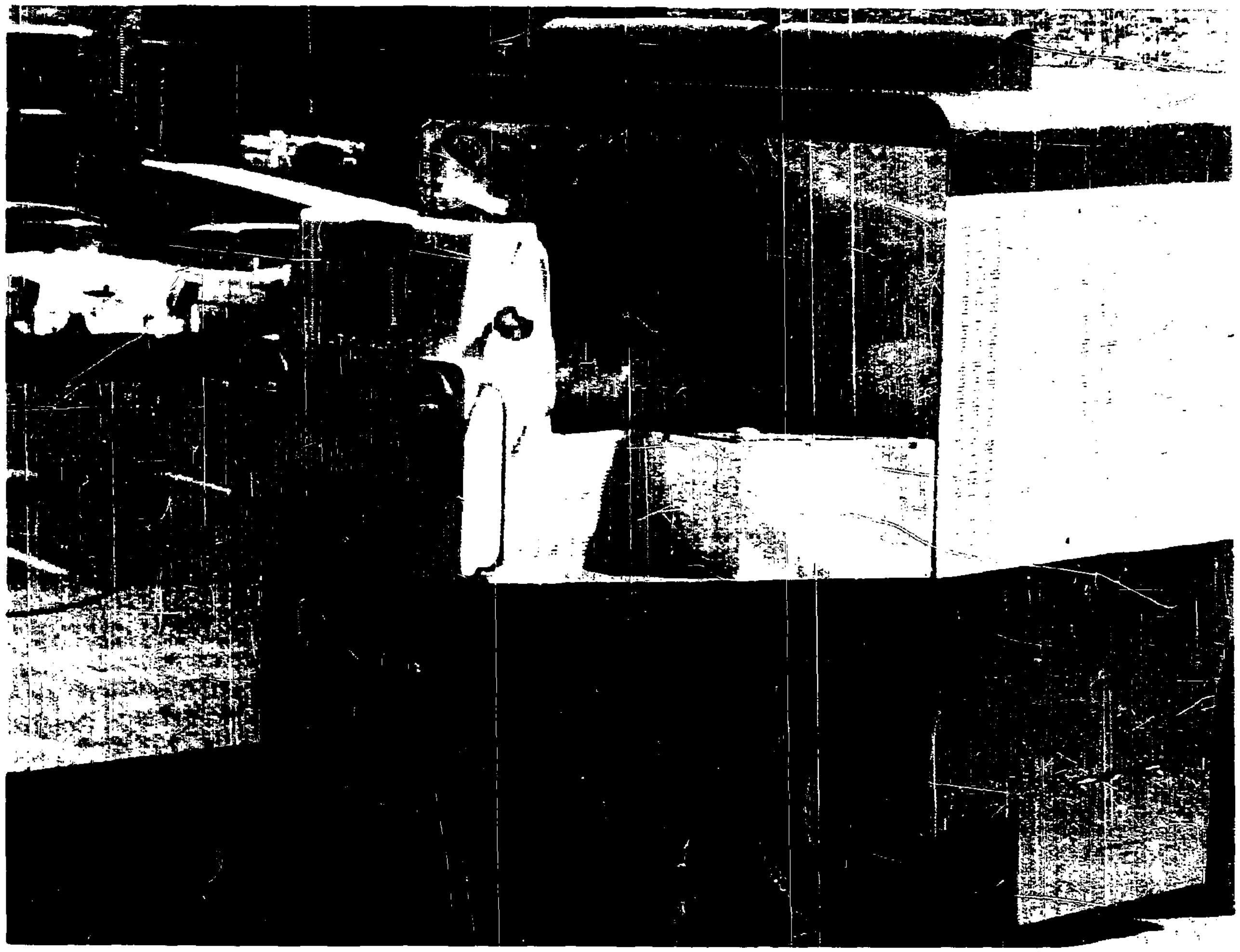

Figure 1. ARDC 100DS decontamination sweeper.

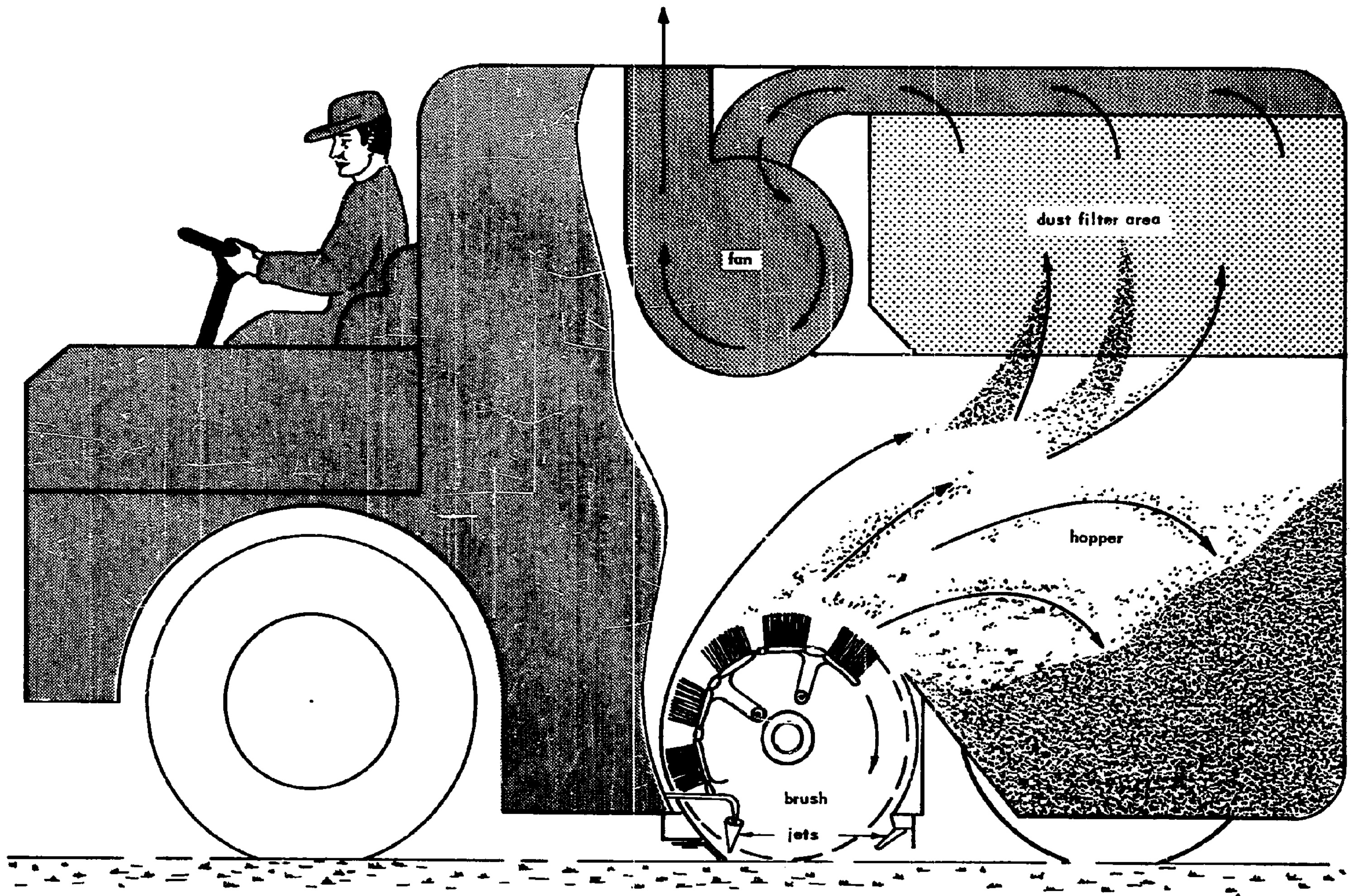

Figure 2. Diagram of 100DS sweeping system.

These test observations and calculations indicated that conversion of street sweepers requires improvement in pickup efficiency, elimination of dust blowing, and provision of shielding. Another inherent problem is the multiplicity of brands with varying mechanical configurations. Conversion equipment for one unit would probably be useless for other brands. The vacuumized commercial units, which perform fairly well as they are, are relatively new and few bases have them.

Because of these various considerations, work was undertaken to study the technical requirements and cost of converting a typical non-vacuumized street sweeper. Since NRDL and the Air Force Special Weapons Center were making tests of methods for improving the pickup of the 100DS, this laboratory's work was concentrated on dust-control methods and shielding. Although basic information already exists for making shielding designs to meet almost any specified requirements, some consideration of the weight-carrying ability of small sweepers and the cost of lead is necessary.

Dust Control and Shielding

As a sample of the third type of sweeper considered, a surplus street sweeper (Figure 3), equipped with a horizontal broom at the rear and a conveyor-fed hopper, was chosen as an experimental unit for studying methods of installing dust-control equipment. Since commercial vacuumized sweepers and the 100DS had good dust control, a similar approach was selected for a feasibility study design for the experimental sweeper. A design air flow of 2500 cfm, similar to that used in the commercial vacuum unit, was selected for preliminary design and cost estimates. To insure adequate velocities in critical areas, a shroud almost touching the ground was considered necessary. As noted earlier, the expected particle size of the fallout to be handled was the governing factor in the selection of a dust-separation method. After a review of available information, a particle size of 25 microns was selected as the minimum to be considered. Since space for conversion could be expected to be limited, cost estimating was based on the use of cyclones rather than bag filters for dust control.

Figure 4 shows the dust-control conversion plan based on these selections of criteria. Table 2 shows estimates of the cost of conversion. Since this cost proved to be impractically high, no actual conversion was made.

The weight-carrying capacity of an ordinary sweeper is another limiting factor in conversion. Because the sweepers are of relatively light construction, the additional weight of shielding and dust-control equipment would be restricted to considerably less than the 7000 pounds shown in Reference 1 as being needed for shielding in early fallout sweeping. The actual weight of additional equipment that a conventional sweeper could carry would probably be about 10 to 15 per that a conventional sweeper could carry would probably be about 10 to 15 percent of the gross weight of the sweeper, or roughly 1000 pounds. If the hopper loading is reduced by about one cubic yard, an additional 1000 pounds could probably be carried. A reduction in hopper loading would have a secondary benefit of reducing the shielding requirement, but would naturally reduce the sweeping capability. However, the allowable additional load would not permit both shielding and dust-control equipment to be added.

Makeshift shielding would have to be adapted for each different brand and model of sweeper. If all 2000 pounds of additional weight is used for shielding, the cost of lead shielding would be about $600. This amount of lead would permit use of the sweeper for decontamination about two days after a contaminating nuclear explosion, depending on the local level of contamination.

Sweeping Rate

Test results[7,8] have shown that normal street sweepers perform most effectively at 2 to 5 mph. With a 5-foot broom this would indicate a practical sweeping rate of about 40,000 square feet per hour, based on 50 percent sweeping time and 50 percent hauling and dumping time.

Table II. Dust-Control Conversion Costs

Conversion Item		Estimated Cost
Cyclones		$1500
Cyclone discharge valves		250
Broom shroud		650
Ductwork		250
Blower and drive		1200
	Total	$3800

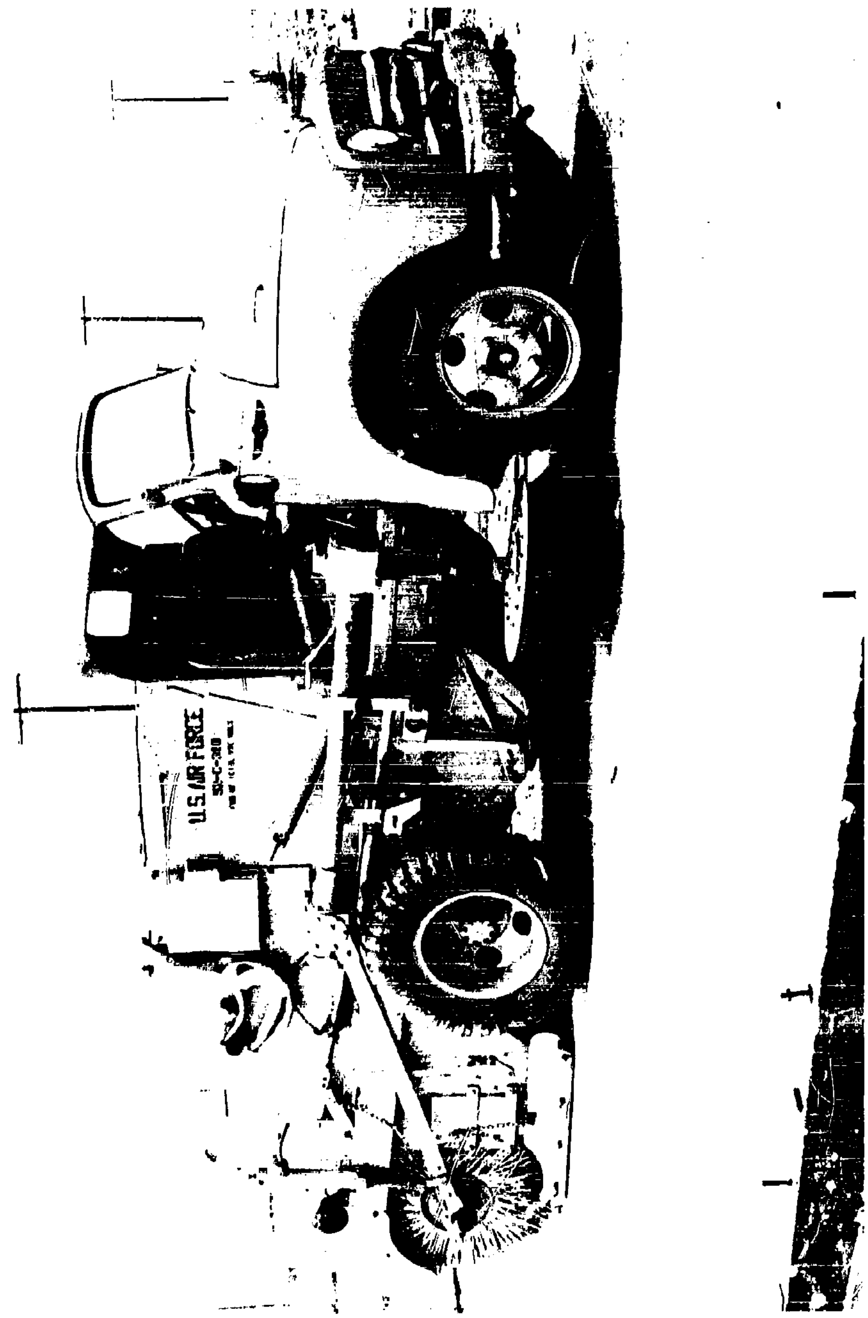

Figure 3. Conventional street sweeper.

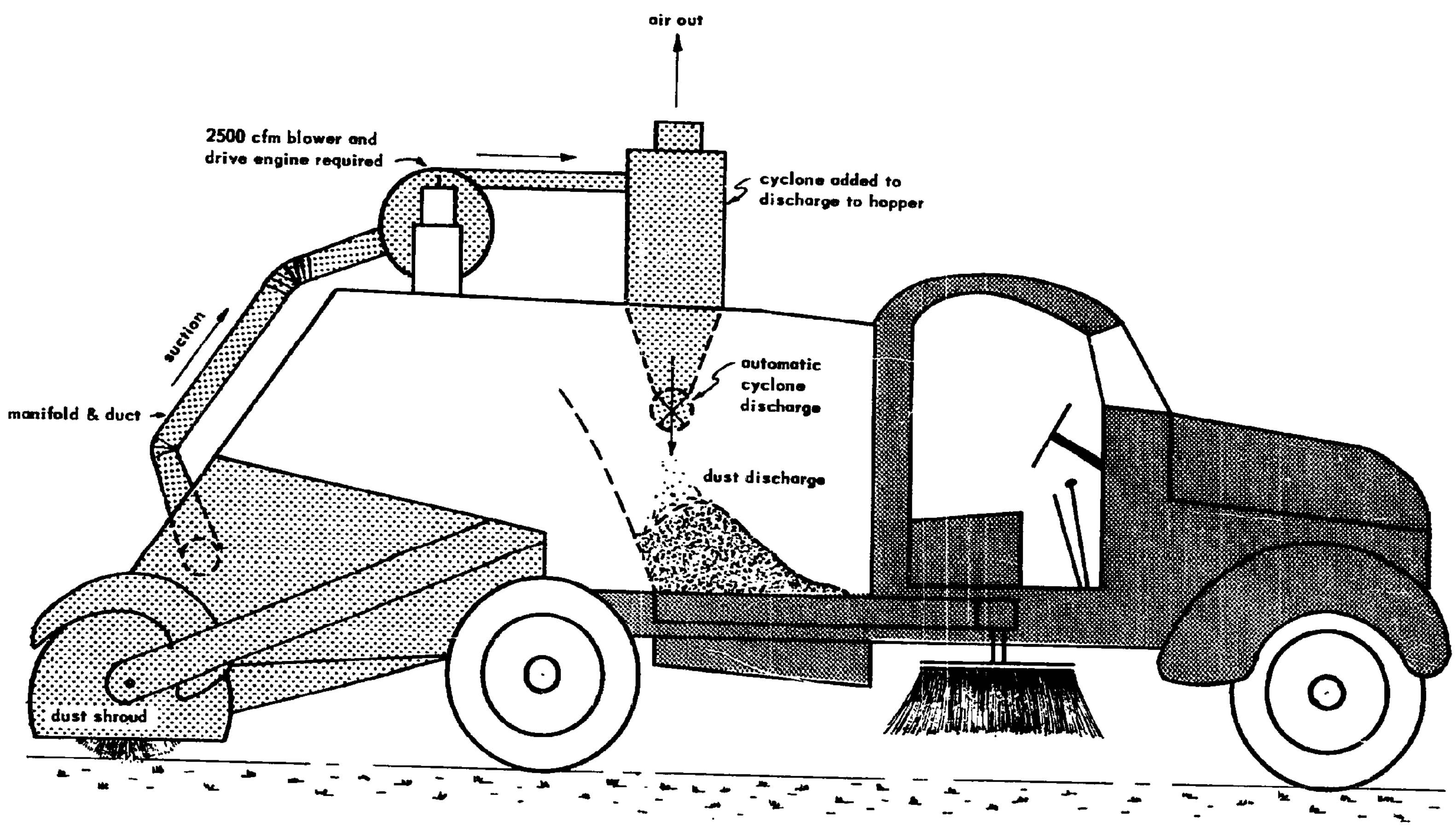

Figure 4. Dust-control conversion for street sweeper.

DISCUSSION

The capabilities of any converted street sweeper are seriously limited by the small amount of shielding that can be carried and by the slow sweeping speed. Since both shielding and dust-control equipment probably cannot be added, a choice between early cleanup or greater cleanup efficiencies would have to be made. With these limitations, the practicability of converting street sweepers to high-rate decontamination is extremely doubtful. The specially designed 100DS is faster and more effective, and one unit is no more expensive ($20,000) than the cost of converting several street sweepers to give an equivalent sweeping capacity. Since the number of bases that require early decontamination is probably quite limited, procurement of special-purpose sweepers seems more practical.

Unconverted street sweepers, however, can be used at later cleanup times and should not be overlooked for this purpose. Table III shows that at about eight days little or no shielding would be required. Dust control would also be a much less important problem at these late times.

Table III. Lead Shielding Estimates (Assumed allowable dose rate = 25 r/hr, divided 40:60 between ground and hopper. Contamination reference level = 3000 r/hr)

Sweeping Time	Shield Thickness	
	Ground	Hopper
1st day	1.5	3.5
2nd day	1.2	2
8th day	0	1

CONCLUSIONS

The ARDC 100DS sweeper meets most of the BuDocks requirements for a high-rate decontamination sweeper and is the best available unit for this purpose. Shielding is needed to permit manned operation in early cleanup if the remote controls are not to be used.

Conversion of street sweepers for high-rate decontamination is not practical, but unconverted sweepers are suitable for late decontamination.

The MC-1 runway sweeper is not suitable for high-rate decontamination.

RECOMMENDATION

An outline of recommended specifications based on the 100DS is shown in the Appendix.

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4. Bureau of Yards and Docks NAVDOCKS TP-PL-13, Radiological Recovery of Fixed Military Installations. Washington 25, D. C., 16 April 1958.

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7. U. S. Naval Radiological Defense Laboratory. Technical Report 196, Cost and Effectiveness of Land Decontamination Procedures, by J. D. Sartor, et al. San Francisco, California, 27 Dec. 1957.

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Appendix

OUTLINE OF SUGGESTED SPECIFICATIONS FOR RADIOLOGICAL DECONTAMINATION SWEEPER

Scope

This specification covers a dual-purpose self-powered pavement sweeper to be used for removal of radioactive fallout from paved surfaces and also for use as a street sweeper for removal of dirt and leaves from streets and alleys.

General Requirements

Description. This sweeper shall be a four-wheeled vehicle with a propulsion engine, a rotary main broom on a horizontal axis, right- and left-hand gutter brooms, an airbroom, a vacuum-type dust-control system, a hopper, operator shielding, and necessary equipment for operation on public highways and for operator control of the sweeping equipment listed herein.

Propulsion and Driving System. This sweeper shall be capable of traveling at speeds up to 35 mph on public highways without overstressing any component. The propulsion system should also allow sweeping at speeds as low as 2 mph. It shall permit turning of the sweeper on a 20-foot radius.

Main Broom. The main broom shall be driven by the propulsion engine or an auxiliary engine in a manner that will allow complete control of the broom speed independently of the forward speed of the vehicle. The broom shall be designed to permit rapid removal and replacement of brushes. It shall be an adjustable, expanding type with a constant diameter until the brushes are worn out. It shall have a raised position for traveling and a control system to provide a positive downward pressure of up to 10 psi over the contact area for sweeping on hard snow. The broom shall rotate to discharge swept material to the hopper.

Gutter Brooms. The gutter brooms shall be 24 inches in diameter, be controlled independently so that the right- and left-hand brooms can be raised or lowered, and be operated whether or not the sweeper is moving or the main broom is operating. Adjustment for wear shall be provided and the support and drive mechanism shall permit a 15-degree tilt of the broom.

Air Broom. The air broom shall consist of a horizontal air manifold, the same length as the main broom and located parallel to it 4 inches behind in the direction of travel. The manifold shall be supplied with compressed air to maintain 20 psi throughout the manifold while air is discharging through jet nozzles pointed downward at the pavement. The jet nozzles shall be 2 inches above the pavement with a maximum 4-inch center-to-center spacing, and shall discharge a total of 2 cfm per nozzle. A shut-off control near the operator shall be provided.

Vacuum Dust-Control System. The dust-control system shall cause all dust stirred up by sweeping to be drawn through a bag filter system for removal of 99 percent of all particles larger than 10 microns in diameter. The system blower operations shall be controllable independently of the forward motion of the sweeper. The bag filters shall be equipped with a shaker mechanism to clean the bags and cause accumulated dust to drop into the hopper.

Dirt Hopper. Swept material shall be contained in a 4-cubic-yard hopper. The hopper shall open by operation of controls at the driver's seat, and all accumulated dirt or fallout should discharge freely, within one minute.

Shielding. The sweeper shall be equipped with a lead shield one inch thick interposed between the hopper and the operator in a manner so that a straight line from any point in the hopper through any edge of the shield will not pass through the operator's position. Brackets shall be provided for placing 1/2-inch-thick lead plates on both sides of the operator, on the floor beneath him, and in front and back of him so that additional shielding can be attached to protect the operator from radiation from fallout on the ground. The sweeper shall be designed to provide the necessary structural strength to carry this shielding.

Performance Requirements. The sweeper shall be capable of sweeping pavement covered with radioactive fallout at a rate of 5000 square feet per minute while removing 95 percent of a fallout material consisting of granular silica containing one part by weight of particles ranging in size from 5 to 25 microns, two parts ranging from 25 to 50 microns, three parts ranging from 50 to 100 microns, three parts ranging from 100 to 150 microns, and one part ranging from 150 to 200 microns, deposited in amounts up to 0.25 pounds per square foot.

Maintenance Requirements. The mechanical components shall be of a reliability comparable to heavy-duty industrial service, and parts requiring replacement in routine service shall be readily accessible. The hopper, brooms, and dust-control system shall be readily decontaminated by hosing or easy removal and replacement of parts.

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